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PLANTING-STOCK STORAGE IN THE CALIFORNIA PINE REGION

H. A. FOWELLS
G. H. SCHUBERT

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Agriculture--Berkeley

PLANTING-STOCK STORAGE IN THE CALIFORNIA PINE REGION

H. A. Fowells and G. H. Schubert[1/]

Introduction

Storing nursery stock sometimes is necessary for forest tree planting in California because of the great variability in climate. Planting sites may be ready either earlier or later than the lifting time at the nursery. As a result, stock may require storage for as long as over-winter to be available for a given planting site at the right time. How long and by what methods stock can be stored are thus questions of real importance. This paper describes several experiments dealing with the storage of planting stock in the pine region of California.

Relatively little information has been published about how, or how long coniferous stock can be stored. Hopkins (3) reported survival of 42 percent for 2-2 white pine and 56 percent for 2-2 white spruce for stock lifted in the fall, stored at 31° - 33°[2/], and planted in July. Survival of 3-0 stock of the same species and under the same conditions was much poorer. More recently Baldwin (2) stored fall- and spring-lifted Eastern white pine, red pine, white spruce, and balsam fir at two cold-storage temperatures and in a cellar. Best stock survival was obtained with spring-lifted stock stored at temperatures just above freezing. No stock withstood storage at 0° to 10°. By contrast Roe (4) reported 61 percent second year survival of 2-1 red pine stock which was lifted in the spring, stored at 14°, and planted in July. Jack pine, left for 3 days at 14°, had good survival, but only 40 to 50 percent of white spruce stock survived the treatment in another test (1). Stoeckeler (5) reported that survival rates of 1-0 pines lifted and transplanted were comparable to rates of pines stored for 5 weeks at 50° before transplanting. Discussing the handling of stock, Wakeley (6) stated that for the southern pines cold storage at 35° to 41° for periods of 3 to 13 weeks gave more erratic results than heel-in storage.

1/ The authors wish to acknowledge participation of Mr. B. M. Kirk, formerly with the California Station, and of Mr. E. A. Morrow in the first two tests reported here.

2/ All temperature measurements are reported in degrees Fahrenheit.

Short-Period Storage

To test methods of storage for relatively short periods in advance of planting, ponderosa pine and Jeffrey pine 1-1 stock were lifted from the Durbin Nursery, Lassen National Forest, 2, 4, and 6 weeks in advance of planned planting dates, in the fall and in the spring. The stock, graded for size, was stored by three methods--cold-cellar, refrigerator, and heeled-in. Trees stored in the cold-cellar and in the refrigerator were packed upright in open-top boxes with sphagnum moss around the roots. The other third of the stock was heeled-in in the usual manner, with pine needles between the rows of transplants and with a roof of boughs over the bed, which was located in a thicket of conifers.

Storage conditions

A continuous hygrothermograph record in the cellar showed that in the fall the temperature ranged from 48° to 54°, and that the relative humidity varied from 84 percent to 100 percent. In the spring the cellar temperature ranged from 40° to 45°, the relative humidity, from 95 percent to 100 percent. The temperature in the refrigerator was set at 41° and fluctuated less than one degree plus or minus; relative humidity changed frequently from about 80 percent to 100 percent.

According to a thermographic record, the temperature in the root zone in the heel-in bed varied from 49° to 61° at the end of September, to 45° to 49° the first of November. The temperature in the tops ranged from 70° to 30°. In the spring the temperatures among the roots and tops ranged from 40° to 49° and 26° to 49°, respectively.

Planting

The stock was outplanted in a split plot, randomized block arrangement with the major split for species and successive splits for period of storage, season of planting, and method of storage. A row of 10 trees was the unit plot. In the fall, trees were planted in one day in early November and in the spring during two days in early April. At the time of planting, freshly lifted stock of the same lot was also planted in the blocks.

The trees were planted in a field, which had been cleared of its original forest cover, at the Feather River Branch Experiment Station near Quincy in the Plumas National Forest. The surrounding ponderosa pine stands are estimated to be of site quality II. The test-field soil is an unclassified stony clay loam. Professional and sub-professional grade employees planted the trees, using mattocks in the side-hole method. Although considerable care was exercised in planting, the rate of planting in trees per man-day was greater than of the usual common labor crews.

Results

Surviving trees were counted and measured at the end of the first year and the data were subjected to the appropriate variance analyses.

Storage time.--Survival of the planted stock decreased with increase in length of storage. Survival was 98 percent, 88 percent, and 76 percent for stock stored 2 weeks, 4 weeks, and 6 weeks respectively. By comparison, 98 percent of the stock planted without storage lived. Storage affected survival more in the fall than in the spring. Only 77 percent of the fall-planted stock lived, compared with 96 percent of the spring-planted stock. In most instances, Jeffrey pine survived as well as, or better than ponderosa pine (table 1).

Table 1.--First-year survival of stock stored for periods of time by 3 methods, in the spring and in the fall 1/

Species and length of storage	Spring			Fall		
	Cellar	Heel-in	Refrig-erator	Cellar	Heel-in	Refrig-erator
	Percent					
Ponderosa pine						
2 weeks	98	100	90	100	98	98
4 weeks	95	100	100	28	85	73
6 weeks	95	98	100	18	47	53
Jeffrey pine						
2 weeks	97	100	95	100	100	97
4 weeks	87	100	98	98	97	95
6 weeks	100	98	100	62	72	72

1/ Basis 2,160 trees.

Storage method.--Trees in the cellar storage had significantly poorer survival (82 percent) than those in the refrigerator (90 percent) or those heeled-in (91 percent). Except for stock stored only 2 weeks, losses of cellar-stored stock were greater in the fall than in the spring.

Height growth.--Height growth during the first year varied inversely with the length of storage; the longer the storage, the shorter the terminal growth. Method of storage and season of planting had no effect on first-year growth.

Over-winter Storage

In a test of over-winter storage, 1-1 ponderosa pine and Jeffrey pine stock was lifted in late November and sorted into 3 size classes, by species, on the basis of stem height. Each size class, large, medium, or small, contained one-third of the trees. Within the size classes, the trees were sorted as to the presence or absence of a hard over-winter bud. Each bud and size class then was divided into thirds, one of which was placed in cold storage, the second heeled-in, and the third outplanted. The following spring, after 4-1/4 months, another group of trees of the same lot, similarly sorted, was lifted and planted simultaneously with the stored stock. There were 1,440 trees in each of the two storage treatments and in the lots planted in the fall and in the spring without storage--a total of 5,760 trees in the experiment.

Storage conditions

The stock stored in the refrigerator was packed with wet moss in boxes, with the tops of the trees exposed. The temperature was maintained at $38^{\circ} \pm 3^{\circ}$ until about 3 weeks before the end of the storage period. At that time the refrigerating system broke down, and when the failure was discovered after 3 or 4 days, temperature in the storage room had risen to 50°. The stock was immediately covered with snow as a substitute for mechanical refrigeration and maintained that way for 2 weeks until the system was repaired. How much the short period of rising temperature and subsequent emergency method of cooling affected results could not be fully determined, but the effect evidently was not great. When the refrigerated stock came out of storage, it appeared on the whole to be in better condition than the heeled-in stock. Furthermore, survival of the stock after planting was reasonably consistent with results from other experiments described in this report. Some of the stock was moldy and a few trees were discarded because of slipped bark, but these failures cannot be attributed to the temporary change in method of cooling.

The heeled-in stock was treated as described earlier. A thermograph with the element 5 inches below the soil surface in the bed, showed the lowest temperature to be 32° in January and the highest, 44° in March. The daily amplitude was 2° to 3°.

The trees did not dry out in the refrigerator or in the heel-in bed. The moisture content on a waterfree basis, of spring-lifted stock, heeled-in stock, and refrigerated stock was 134 percent, 186 percent, and 171 percent, respectively. Moisture content was measured by xylene distillation.

Planting

Stock of the 2 species and 4 treatments, that is: (1) fall planted, (2) spring planted, (3) heeled-in and spring planted, and (4) refrigerator-stored and spring planted, and of the size and bud classes within treatments was planted on a split plot, randomized block design. The trees were planted in the test field already described by the same technique. Rows of 30 trees constituted the unit in the design. Trees were counted and measured at the end of the first and second years.

Results

Storage method.--Survival at the end of the first year for the four treatments was: fall planted, 94 percent; spring planted, 96 percent; heeled-in, 91 percent; and stored in refrigerator, 81 percent. Practically no losses occurred during the second year. On the basis of statistical significance, fall and spring planting without storage were better than the other two treatments and refrigerator storage was the poorest. However, the heeled-in and refrigerated trees were still well within the range of acceptable survival for field planting.

Size and bud grades.--The survival of large and medium sized stock (92 percent) was statistically significantly higher than that of the small stock (88 percent). For practical purposes, the difference is of no consequence. The statistical significance simply indicates the high sensitivity of the data which resulted from the design of the test and the small variances. Storage methods did not affect one size class more than another; that is, the size class x treatment interaction was not significant. Survival of trees with buds was 2 percent higher than that of trees without buds (a statistically significant difference) but storage method did not affect one bud class more than another. There was no statistically significant difference in overall survival between the two species.

Height growth.--Height growth by the end of the second year, averaging nearly 3 inches, was greatest for the fall-planted stock and least for the heeled-in stock. Growth of trees in both stored lots was significantly less than that of trees planted in the fall without storage:

	Growth, inches
Fall planted	3.25
Spring planted	3.02
Heeled-in	2.66
Refrigerated	2.80

Storage Temperature and Packing Material

After the foregoing experiments had demonstrated that stock could be stored in refrigeration for 4 or 5 months, tests were planned to find more favorable refrigeration conditions.

Storage conditions

The first of two experiments tested three temperatures, 0°, 32°, and 41°; three periods, 1, 4, and 7 months; and three species of trees, sugar pine, ponderosa pine, and Jeffrey pine, 1-1 stock. Following storage, 2 portions of the stock were conditioned for 1 and 2 weeks by exposure to a temperature of 55°.

In a second experiment, the temperature range was narrowed to 23°, 32°, and 36°; storage time to 3 months and 6 months; and kinds of trees to only one species and class, 1-1 ponderosa pine. Stock was obtained from Shasta Nursery, Shasta National Forest. Also, the additional important factor of packing material was introduced. Vermiculite, sawdust, shingle tow, and peat moss were used for packing. After the roots were covered with packing material, each bundle was wrapped in heavy waxed paper.

Temperature and relative humidity ranges in the storage rooms were:

Nominal temperature (degrees)	Temperature range (degrees)	Humidity range (percent)
23	20 - 25	50 - 98
32	31 - 33	80 - 90
36	34 - 38	62 - 88

Relative humidity changed rapidly with temperature fluctuation. At the end of the period the trees were planted in gallon cans arranged in a randomized block design in the greenhouse. Lateral or terminal growth at the end of 2 months was used as evidence of survival.

Results

Temperature.--Storage temperature definitely affected the survival of the stock. No trees lived after storage at 0° or 23°. The critical temperature appeared to be about 32°. In the first test the survival rate was high, except for sugar pine, after storage at 32° for 4 months (table 2). Comparisons with the stock stored at 41° longer than 1 month were not possible because of a refrigeration failure. However, after 7 months storage at 32°, the survival rate dropped to 23 percent for both ponderosa and Jeffrey pine. Freezing of plant tissue may have occurred during this storage period; ice crystals were found in the bundles of stock. In the second test, survival of the trees stored at 36° was better (highly significant) than the survival of those stored at 32° (table 3). In most instances the longer the periods of storage the poorer was the survival of the stored trees.

Table 2.--Survival of planting stock stored for 3 periods at 41°, 32°, and 0° 1/

Species and storage period	Survival when storage temperature was --		
	0°	32°	41°
	percent		
Sugar pine			
1 month	0	70	83
4 months	0	23	2/ 23
7 months	0	0	2/ 0
Ponderosa pine			
1 month	0	100	100
4 months	0	93	2/ 90
7 months	0	23	2/ 3
Jeffrey pine			
1 month	0	97	100
4 months	0	97	2/ 70
7 months	0	23	2/ 3

1/ Basis, 810 trees.

2/ Stock exposed to strong ammonia fumes during refrigeration. Hence these data do not represent the results of proper storage and were rejected from the analysis.

Table 3.--Survival of ponderosa pine planting stock stored for 3 and 6 months at 3 temperatures and packed in 4 materials[1]

Packing material	Stored three months at -			Stored six months at -			Total
	23°	32°	36°	23°	32°	36°	
	percent						
Vermiculite	0	84	96	0	71	98	349
Peat moss	0	87	96	0	70	82	335
Sawdust	0	65	85	0	81	79	310
Shingle tow	0	92	94	0	46	71	303
Total	0	328	371	0	268	330	---

1/ Basis 1,152 trees.

Packing material.--Both vermiculite and peat moss were better packing material on the average than sawdust and shingle tow (table 3), and analysis of variance showed the differences were statistically significant. However, from the standpoint of practical evaluation, it seems by no means certain that any of the materials is definitely superior or inferior to the others. Considering the four combinations of storage temperature and time, vermiculite, sawdust, and shingle tow were each best once; shingle tow at 32° and 3 months, sawdust at 32° and 6 months, vermiculite at 36° and 6 months. In the fourth case, 36° and 3 months, vermiculite and peat moss tied for first place. The results are therefore regarded as inconclusive.

Conditioning.--Conditioning the stock for periods of 1 or 2 weeks at 55° had no statistically significant effect on the rate of survival.

Summary and Discussion

The first two of four experiments dealing with storage of nursery stock demonstrated that refrigeration storage is feasible but results in some reduction in survival and growth. The first experiment tested 2, 4, and 6 weeks' storage in a cold cellar, a heel-in bed, and in a refrigerator set at 41°, in two different seasons--spring and fall. After field planting, all the stock stored in the spring survived satisfactorily (87 to 100 percent). In contrast, the autumn-stored trees showed some decline in survival after 4 weeks' storage and serious declines after 6 weeks. Growth tended to decline with increasing length of storage.

The second experiment compared over-winter storage for 4-1/4 months by two methods--heeled-in and refrigerated at 38°--with direct field planting in the spring and fall. Despite a mechanical failure which somewhat disturbed the refrigeration schedule, field survival of the refrigerated stock after one year was 81 percent, a reasonably satisfactory survival. The direct field planted trees survived best of all, and heeled-in stock was intermediate in survival. The direct field-planted stock also grew faster than the stored trees.

The third and fourth tests, restricted primarily to a search for better storage conditions, showed that (1) 36° is apparently close to the optimum temperature, and (2) below freezing temperatures of 23° and 0° resulted in total failures in survival. The fourth experiment also tested 4 different packing materials: Vermiculite, peat moss, sawdust, and shingle tow. Vermiculite proved to be the most satisfactory of the four on the average, and peat moss second best, but the results are regarded as indicative rather than conclusive.

Grading the stock by size and also by presence or absence of a hard winter bud resulted in no substantial differences in subsequent survival. Attempts to condition the stock by exposing the trees to 55° temperatures for 1- and 2-week periods before outplanting resulted in no improvement in survival.

Possibilities for practical application

The experiments prove beyond question that under the conditions described, the most commonly planted species of nursery stock in California, ponderosa pine and Jeffrey pine, can be lifted in the fall and stored under artificial refrigeration for up to 6 months. The reductions in field survival and growth that resulted from storage appear to be less objectionable than the losses which may result when climate at the nursery and planting sites are not in phase. Some planting sites are at their best before stock can be lifted at the nursery; some planting sites become ready only after growth has become active in the nursery.

Indications are quite definite that the best storage temperature is close to 36°, and stock should be stored at temperatures within a narrow range between about 36° and a little above 32°. Storage at temperatures just above freezing seems to minimize the development of mold, which was quite noticeable at 41°. Temperatures at the freezing point or lower were decidedly harmful.

It should be noted that in two of the experimental trials, the refrigeration system developed difficulties. In full-scale storage operations, such breakdowns could be disastrous. For cold storage, then, a first requisite is a reliably operating system, repairs for which are obtainable on short notice. And the system must have both the cooling capacity and accurate control to maintain temperatures within a narrow range just above freezing. Furthermore, we may reasonably assume that high relative humidities should be maintained to minimize desiccation of the stored plants.

Alternatively, stock can be stored overwinter if properly heeled-in. In the tests reported here, the heel-in beds were adjacent to the planting sites; hence no problems of seasonal difference arose. Locating the heel-in beds close to the planting site appears to be a desirable procedure.

Opportunities for further study

Although the experiments have shown that over-winter storage is biologically possible, both heeling-in and refrigeration caused some increase in mortality, compared with stock planted out immediately after lifting. In at least one case the loss did not result from desiccation of the stock, since the stored stock had a higher moisture content than the freshly lifted stock. How to halt the decline in stock vitality is a problem yet to be solved. The ultimate solution would be storage accompanied by some conditioning process which might increase the vitality of the stock. An attempt to condition the stock by subjecting it to a higher storage temperature just before planting, however, had no effect; survival was neither increased nor decreased significantly. Yet there must be some treatment which can be discovered to bring stock to a state of growth readiness comparable to or better than that of trees left in the ground all winter.

That the stored trees grew slightly less than freshly lifted trees is understandable because the abnormal environment of the stored stock may have retarded the beginning of active growth and certainly caused some reduction in reserve food in the plants. The comments concerning need to increase vitality by some treatment also apply to this problem of stimulating growth after storage.

It is difficult to rationalize the complete failure of stock stored at temperatures below freezing when some similar experiments from other regions have not ended in heavy mortality of the stock. Although there may be differences among species in sensitivity to storage treatments and freezing, explanations on this basis are not justifiable without further trials including various species.

The possibilities for discovery of superior packing materials undoubtedly are extensive. The experiments described in this report tested only four. Wholly different materials could be tested, as well as the original four after modifications such as by sterilizing.

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